PCT

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) **International Patent Classification** [6] : G06K 9/36, 9/46	**A1**	(11) **International Publication Number:** **WO 99/10837**
		(43) **International Publication Date:** 4 March 1999 (04.03.99)

(21) **International Application Number:** PCT/US98/17530

(22) **International Filing Date:** 24 August 1998 (24.08.98)

(30) **Priority Data:**
60/056,968   26 August 1997 (26.08.97)   US
09/138,061   21 August 1998 (21.08.98)   US

(71) **Applicant:** DIGIMARC CORPORATION [US/US]; Suite 500, One Centerpoint Drive, Lake Oswego, OR 97035 (US).

(72) **Inventors:** RHOADS, Geoffrey, B.; 304 S.W. Tualatin Loop, West Linn, OR 97068 (US). DAVIDSON, Clay; 17374 Lake Haven Drive, Lake Oswego, OR 97035 (US). RODRIGUEZ, Anthony; 3104 N.E. 31th Avenue, Portland, OR 97212 (US).

(74) **Agent:** GALBI, Elmer; 13314 Vermeer Drive, Lake Oswego, OR 97035 (US).

(81) **Designated States:** AU, CA, FI, JP, MX, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

---

(54) **Title:** METHOD AND APPARATUS FOR WATERMARKING VIDEO IMAGES

(57) **Abstract**

Embedding a watermark in an image by changing selected DCT coefficients (301) in the blocks and macro blocks of coefficients which represent the image. The changes in the blocks that comprise each macro block are done in a coordinated manner so that the phase of the watermark signal is preserved across the block boundaries. The bit rate of the image signal is preserved by maintaining a count that represents the amount that the bit rate has been increased by changes in coefficients less the amount that the bit rate has been decreased by changes in the coefficients.

1   METHOD AND APPARATUS FOR WATERMARKING VIDEO IMAGES

2

3   **Field of the Invention:**

4   This invention relates to stenography, to copy protection and to applying and

5   detecting digital watermarks in video images.

6

7   **Background of the invention:**

8   The advent of technology for storing images on digital media has increased the

9   need for a method to protect against piracy. Images stored on prior forms of media

10   (e.g. VHS, Beta, audiotapes, etc.) are inherently degraded when copied. Images

11   stored on digitally encoded media can be copied with no degradation; therefore,

12   perfect copies of copies of copies, etc. can be made.

13

14   The introduction of Digital Versatile Discs (DVD) containing movies has created

15   increased incentives for both casual and professional unauthorized copying. At the

16   movie industry's urging, technology has been put in place to protect against simple

17   duplication of DVD disks using equipment available to unsophisticated consumers.

18   This is similar to the protection that exists which prevents one from duplicating a

19   VCR tape by connecting together two commercially available VCRs.

20

21   While such protection mechanisms protect against some types of copying, a

22   personal computer connected to a DVD device present a much more complicated

23   problem. Open architecture devices such as personal computers reproduce the

24   signals in the "clear" and such devices have many entry points, which can be used

25   to duplicate material once it is in the "clear". The present invention uses digital

26   watermarks to address the above described problem. The present invention also

27   has other applications

1

2   It is known that to facilitate the detection of digital watermarks one can insert a

3   watermark signal that forms a grid. The grid can be used to determine orientation

4   and scale. With the present invention the data signal and the grid signal are

5   integrated into a single watermark signal in such a manner that the visual artifacts

6   introduced by the watermark are minimized.

7

8   In applications such as DVD, an important factor that needs be considered is the bit

9   rate of the bit stream. There are disadvantages if introduction of a watermark into a

10   bit stream changes the bit rate. For example if images are going to be recorded on

11   a medium such as a DVD disc, increasing the number of bits in the bit stream will

12   decrease the number of images that can be recorded on a single disk. It is known

13   that, in general, adding a watermark to a stream of images will increase the number

14   of bits in the bit stream. The present invention provides a method and apparatus,

15   which preserves the bit rate even though watermarks are introduced into the

16   images.

17

18   Summary of the invention:

19   The well-known JPEG and MPEG data compression techniques transform images

20   utilizing a discrete cosine transform (DCT) which produces a matrix of DCT

21   coefficients. These coefficients are arranged into blocks (e.g. into 8 by 8 blocks of

22   coefficients). The blocks of DCT coefficients are in turn arranged into macro blocks

23   (e.g. into 16 by 16 arrays containing four 8 by 8 blocks). With the present invention

24   selected DCT coefficients in each block are slightly increased or slightly decreased

25   in response to a watermark signal. The changes in the blocks that comprise each

26   macro block are done in a coordinated manner so that the phase of the watermark

27   signal is preserved across the block boundaries. By preserving the phase across

2

1   block boundaries. a detectable grid is formed which can be used as an orientation

2   and scaling grid.

3

4   The present invention also maintains the bit rate of the image signal. The bit rate of

5   the signal is preserved by maintaining a count (referred to as the cumulative change

6   count) that represents the amount that the bit rate has been increased by changes

7   in coefficients less the amount that the bit rate has been decreased by changes in

8   the coefficients. If at any time the cumulative change count exceeds a pre-

9   established limit, coefficient changes that decrease the cumulative change count

10 continue; however, coefficient changes that increase the cumulative change count

11 are suspended. The suspension of coefficient changes that increase the

12 cumulative change count continues until the cumulative change count falls below

13 the pre-established limit. The above described process can be described as

14 selectively changing the intensity of a watermark signal in a bit stream so as to

15 prevent the entropy of the combined signal from exceeding a pre-established limit.

16 **Brief Description of the Figures:**

17 Figure 1 is a diagram illustrating how the pixels in an image are arranged into blocks

18 and how the resulting DCT coefficients are numbered.

19

20 Figure 2 is a diagram, which shows how the blocks of DCT coefficients are arranged

21 into macro blocks.

22

23 Figure 3 is a program flow diagram showing how the coefficients in each block of a

24 macro block are treated so as to preserve the phase of watermark signal in each

25 macro block.

26

3

1   Figure 4 is a program flow diagram showing how the bit rate in the data stream is

2   maintained constant.

3

4   **Description of preferred embodiments:**

5   The well know MPEG (Motion Picture Expert Group) and JPEG (Joint Photographic

6   Expert Group) image compression techniques use a DCT (Discrete Cosine

7   Transform) to generate a matrix of coefficients.   The preferred embodiment of the

8   invention shown herein slightly modifies the DCT coefficients (either slightly

9   increases or slightly decreases the value of the coefficients) so as to embed a

10   digital watermark in the image. Such a digital watermark can later be detected by

11   conventional cross correlation techniques.

12

13   As illustrated in Figure 1, the MPEG and JPEG techniques divide an image into 8 by

14   8 blocks of pixels. Each block of pixels is then used to generate an eight by eight

15   block of DCT coefficients.   The 8 by 8 blocks of coefficients are divided into "macro

16   blocks", each of which consist of four of the original blocks. This is illustrated in

17   Figure 2. The rows and columns of DCT coefficients in each block are numbered

18   from top to bottom and left to right as illustrated in Figure 1. The first row and the

19   first column are designated as the "0" row and "0" column.

20

21   Certain of the DCT coefficients in each block are selected as the coefficients that

22   will carry a selected bit of the digital watermark signal. In the preferred embodiment

23   the three coefficients circled in Figure 1 are used to carry the first or "0" bit of the

24   watermark data signal. These three coefficients are modified, that is, either slightly

25   increased or slightly decreased depending upon the value of the "0" bit of the

26   watermark data. In a similar manner other coefficients are slightly changed in order

27   to carry the other bits of the watermark signal.

1

2　One aspect of the present invention is directed to insuring that the sinusoids

3　generated by the changes made to the DCT coefficients are continuous, that is, in-

4　phase across the four blocks that constitute each macro block. First, if the

5　sinusoids that carry the watermark are continuous across each macro block, there

6　will be less edge effects and the watermark will be less visually noticeable. Second,

7　the sinusoids which are continuous over the four blocks of each macro block create

8　a low level orientation or grid signal. This low level grid signal can be detected to

9　determine the orientation and scale of the watermark. The grid signal can then be

10　detected using the cross correlation techniques. Cross correlation detection

11　techniques are for example shown in copending patent application 08/649,149 filed

12　5/16/96 and in issued patent patents 5,748,763 and 5,748,783.

13

14　If certain DCT coefficients in adjacent blocks are modified in the same direction, the

15　resulting sinusoids will not be continuous across block boundaries.   With the

16　present invention the changes made to the coefficients of each of the four blocks in

17　a macro block are coordinated so that the resulting sinusoids will be continuous

18　across block boundaries within each macro block. The changes are coordinated

19　using the rules explained below.

20

21　The blocks in each macro block are numbered as shown in Figure 2. Block one is

22　considered the base block. The coefficients in this block are changed in a

23　conventional way by the associated bits of the watermark signal.   Note, the

24　following paragraphs relate to how the coefficients which are circled in Figure 1 are

25　changed in response to the "0" bit of the watermark. It should be understood that

26　other coefficients must be similarly changed to carry the other bits in the watermark

27　data.

1

2   In block 1, the coefficients that are circled in Figure 1 are slightly increased or

3   slightly decreased in response to the "0" bit of the watermark data.   In blocks 2, 3

4   and 4, the circled coefficients shown in Figure 1 are changed in response to the

5   zero bit of the watermark according to the following rules.

6   Block 2: invert the direction of the change if the coefficient is in an odd row.

7   Block 3: invert the direction of the change if the coefficient is in an odd

8   column

9   Block 4: invert the direction of the change if the coefficient is in an odd row

10   or if it is in and odd column, but do not invert the direction of the

11   change if the coefficient is in both and odd row and in an odd column.

12

13   If the above rules are followed the sinusoids generated by the change in the DCT

14   coefficients will be continuous across the boundaries in the four blocks that form

15   each macro block.   These sinusoids will be able to be detected using conventional

16   cross correlation techniques and they can be used as a grid to determine the scale

17   and rotation of the image.   The data bits in the watermark will also be able to be

18   detected using conventional watermark detection techniques.   Thus, the watermark

19   data itself is used to form the grid that can be used to determine scale and rotation.

20

21   Figure 3 is an overall program flow diagram of the above described aspect of the

22   preferred embodiment.   The system accepts a stream of data that represents

23   images.   Block 301 is a conventional device or program module that generates DCT

24   coefficients for the images in the data stream.   These coefficients are sent to a

25   decision unit 302 which separates the data into macro blocks and sends it to units

26   311, 312, 313 and 314 depending upon whether the data represents a block 1, 2, 3

6

1   or 4 in a macro block. Units 311-313 modify the DCT coefficients in order to imbed

2   a watermark signal according to the following rules.

3   Unit 311: modify the coefficients in a conventional manner to imbed

4   watermark.

5   Unit 312: invert the direction of the change if the coefficient is in an odd row.

6   Unit 313: invert the direction of the change if the coefficient is in an odd

7   column

8   Unit 314: invert the direction of the change if the coefficient is in an odd row

9   or if it is in and odd column, but do not invert the direction of the

10   change if the coefficient is in both and odd row and in an odd column.

11   The output of units 322 to 314 is combined by unit 320 back into a single data

12   stream.   It is noted that each of the units shown in Figure 3 could be separate units,

13   which are either programmed, or hardwired to perform the specified functions.

14   Alternatively all the function could be performed in a single programmed computer

15   on a time-shared basis. The unit which generates DCT coefficients is conventional

16   and such units are know and not part of the present invention.

17

18   The previous discussion describes how a watermark can be introduced in the DCT

19   domain. It is noted that the durability of the overall watermarking can be increased

20   by using two watermarks. One watermark can be added by modification of the

21   pixels in the original image in the manner as described in US patents 5,748,763 or

22   5,748,783 and then a second watermark can be added by modification of the

23   coefficients in the DCT domain as described herein.

24

25   Another problem addressed by the present invention is the need to maintain a

26   constant bit rate in a stream of bits representing a series of images even though

27   watermarks are added to the images. It is noted that MPEG and JPEG systems use

1 variable length codes to represent data, hence, adding watermarks generally

2 increases the bit rate of a data stream. Typical a watermark has no correlation with

3 the image into which the watermark is embedded, thus embedding an image in a

4 watermark produces an image which has a higher entropy than the original image.

5 The bit rate of a data stream transmitting an image correlates directly to the entropy

6 of the image.

7

8 Typically the number of codes used to code an image, that is, the number of entries

9 in the Huffman table of a coded image, is relatively large (e.g. 500). However, the

10 changes that occur when a watermark is introduced into an image can be illustrated

11 with following simple example. Consider a data stream that has only four symbols,

12 s1, s2, s3 and s4, which are encoded as follows:

13   Symbol   code

s1	0
S2	01
S3	110
S4	111

14

15 Then consider a data stream as follows:

16   Bit stream: 0011010111010

17   Decoded stream   0/0/110/10/111/0/10

18   Decoded message: s1, s2, s3, s2, s4, s1, s2

19

20 When a watermark is added to an image the bits in the image are slightly changed.

21 In the above simplistic illustrative example, in some situation the symbol s2 would

22 be changed to the symbol s3 and hence the number of bits in a bit stream which

23 transmits the image would be increased. In fact there are mathematical principles

8

1   (not explained herein) which show that when a normally distributed watermark (that

2   is, a watermark with a Gaussian distribution) is added to an image, and the image is

3   transmitted using variable length Huffman codes, the length of the bit stream will of

4   necessity be increased.

5

6   The present invention provides a technique for insuring that when a watermark is

7   added to a data stream, the bit rate will be maintained constant. It is noted that the

8   present invention does not violate the above-described mathematical principle,

9   because with the present invention, some of the redundancy normally used to

10   watermark images is in certain circumstances decreased.   That is in certain

11   circumstances the intensity of the watermark is decreased.

12

13   With the present invention, the watermark is modified in response to characteristics

14   of the image. Thus, to some extent the watermark is correlated to the image into

15   which the watermark in embedded. In this way a watermark can be embedded into

16   an image and the entropy of the combined image and watermark will be

17   substantially equal to the entropy of the watermark alone.

18

19   With the present invention, the system maintains a cumulative count of the amount

20   that the coefficients have been changed to any point in time. That is, the amount of

21   positive changes less the amount of negative changes made since the beginning of

22   the bit stream is tracked. This amount is herein referred to as the cumulative

23   change count. If at any time, the cumulative change count exceeds a pre-

24   established positive limit, no further positive changes are made.

25

26   Normally it is only necessary to insure that changes do not increase the bit rate

27   unduly; however, in some instances it may also be desirable to insure that changes

1   do not unduly decrease the bit rate. If this is desired, the same technique as

2   described above can be used to insure that the cumulative change amount does not

3   exceed a pre established negative limit. That is, if the cumulative change amount

4   exceeds a pre-established negative value, positive changes continue in a normal

5   manner, but no further negative changes are made.

6

7   The magnitude of the pre-established maximum (and in both a positive and negative

8   direction) are established at the values which constitutes the change in bit rate

9   which can be tolerated in a particular system.

10

11   Figure 4 is a program flow diagram showing how the data rate is maintained

12   constant not withstanding the fact that watermarks are added to the images in the

13   data stream. Block 403A shows that a limit on the amount of positive changes that

14   can be made to DCT coefficients is established and stored. Blocks 403C shows

15   that the cumulative change amount is stored. The cumulative change amount is the

16   amount of positive changes less the amount of negative changes that have been

17   made to coefficients since the start of the data stream.

18

19   The DCT coefficients are calculated in the normal manner as indicated by block

20   401. Likewise the change in each the DCT coefficients needed to embed the

21   watermark is also calculated in the normal manner as shown by block 405. Block

22   405 shows that a check is made to determine if the needed change in a particular

23   DCT coefficient is positive or negative. Block 409 indicates that if the change is

24   positive a check is made to determine if the maximum allowable cumulative change

25   amount stored in block 403A will be exceeded if the change is made.

26

1   Blocks 415, and 417 indicate that the coefficients will only be changed, if the

2   change does not cause the cumulative change amount to exceed the limit in 403A.

3   Finally as indicated by blocks 425 and 427, the cumulative change amount in

4   register 403C is incremented or decremented if a change to the coefficients is in

5   fact made. Block 431 indicates that the coefficients are sent to the output of this

6   process and they are then transmitted and processed in a normal manner.

7

8   It is noted that the present invention relates to embedding a watermark in an image.

9   Various know techniques can be used to detect watermarks embedded in images

10 utilizing the present invention.   For example techniques such as those described in

11 US patents 5,748,763, and 5,748,783 or in the "Communications of the ACM" July

12 1998/vol. 41, No.7. or in pending US applications serial number 08/746,613 filed

13 11/12/96 and serial number 08/649,419 which was filed 5/16/98 (all of which are

14 hereby incorporated herein by reference) could be used.

15

16 While the process has been described above as one where a change is either made

17 or not made, it should be understood that alternatively, the amount of the change

18 could be decreased if the limit in the cumulative change value is being approached.

19 It is also noted that the system shown in Figure 4 prevents the cumulative change

20 value from exceeding a pre established positive limit. Since adding a watermark to

21 an image generally increases the entropy of the image and since Huffman code

22 tables are normally constructed such that an increase in entropy result in increased

23 bit rate, the use of only a positive limit is normally appropriate.   However, in some

24 situations, it may be appropriate to tract if the cumulative change amount exceeds a

25 limit in both the positive and negative directions.   Such a check could be added to

26 Figure 4 prior to block 427.

1

2   It is recognized that by implementing the present invention, the strength of the

3   watermark is in some cases reduced. However, the reduction is not sufficient to

4   prevent detection of the watermark. The changes made with the above invention

5   merely lower the intensity of the watermark in a selective manner, thus in some

6   instances more processing may be required to detect the watermark.

7

8   In many systems, each Huffman code covers several symbols. In such systems the

9   calculation indicated by block 405 is not the change in a single symbol that results

10   from adding a watermark to the image. In such systems the calculation indicated by

11   block 405 is a calculation of the change that results in the bit string of whatever

12   combination of symbols used in the Huffman code to represent a symbol. In some

13   cases the calculation might have to be done over several combinations of symbols.

14

15   It is also noted that various aspects of the present invention are shown herein in a

16   single preferred embodiment. Other alternative embodiments could use one but not

17   all aspects of the present invention. For example the part of the present invention

18   that relates to maintaining bit rate could be used in embodiments which do not use

19   macro blocks to establish an orientation grid. Likewise the aspect of the present

20   invention which relates to the use of macro blocks could be used without the part of

21   the invention that relates to maintaining a constant bit rate. Finally, while the

22   invention has been shown in an embodiment that inserts a watermark in the DCT

23   domain, the invention could be used in applications where watermarks are inserted

24   in other domains.

25

26   While the invention has been shown and described with respect to preferred

27   embodiments of the invention, various changes in form and detail could be made

12

1   without departing from the spirit and scope of the invention. The applicant's

2   invention is limited only by the appended claims.

1   I claim:

2

3   1.   A method for adding a multibit watermark to an image comprising,

4   generating DCT (Discrete Cosine Transform) coefficients representing said image,

5   said coefficients being arranged in blocks, said blocks being arranged into

6   macro blocks,

7   adjusting said coefficients in accordance with the bits of said watermark to embed

8   said watermark in said image, said adjustments being made in a direction

9   that sinusoids generated by said adjustments are in phase across block

10   boundaries in each macro block.

11

12   2.   The method of claim 1 wherein each of said macro blocks contains four blocks.

13

14   3.   The method of claim 2 wherein the blocks in each macro block are numbered

15   one, two, three and four and wherein the coefficients in each block are arranged in

16   rows and columns, alternate of said rows and columns being designated even and

17   odd rows and columns.

18   the coefficient in block one being changed directly in response to the bits of said

19   watermark, the bits in blocks two, three and four being changed in accordance with

20   the following rules:

21   Block 2: invert the direction of the change if the coefficient is in an odd row.

22   Block 3: invert the direction of the change if the coefficient is in an odd

23   column

24   Block 4: invert the direction of the change if the coefficient is in an odd row

25   or if it is in and odd column, but do not invert the direction of the

26   change if the coefficient is in both and odd row and in an odd column.

1

2   4. A system for adding a muitibit watermark to an image comprising,

3   means for generating DCT (Discreet Cosine Transform) coefficients representing

4   said image, said coefficients being arranged in blocks, said blocks being

5   arranged into macro blocks,

6   means for adjusting said coefficients in accordance with the bits of said watermark

7   to embed said watermark in said image, said adjustments being made in a

8   direction that sinusoids generated by said adjustments are in phase across

9   block boundaries in each macro block,

10   whereby the same changes which represent said watermark form a grid which can

11   be used to detect the scale and rotation of said watermark.

12

13   5. The system of claim 4 wherein each of said macro blocks contains four blocks.

14

15   6. The system of claim 5 wherein the blocks in each macro block are numbered

16   one, two, three and four and wherein the coefficients in block are in rows and

17   columns, alternate of said rows and columns being designated even and odd rows

18   and columns,

19   The coefficient in block one being changed directly in response to the bits of said

20   watermark, the bits in blocks two, three and four being changed in accordance with

21   the following rules:

22   Block 2: invert the direction of the change if the coefficient is in an odd row.

23   Block 3: invert the direction of the change if the coefficient is in an odd

24   column

25   Block 4: invert the direction of the change if the coefficient is in an odd row

26   or if it is in and odd column, but do not invert the direction of the

27   change if the coefficient is in both and odd row and in an odd column.

15

1

2   6.   A method of embedding a watermark into an image comprising,

3   dividing the elements which form said image into blocks and arranging said blocks

4   into macro blocks,

5   introducing said watermark into the blocks in each macro block in an orientation

6   such that the resulting sinusoids are in phase across block boundaries in each

7   macro block,

8   whereby said watermark can be used to both carry data and form a grid which can

9   be detected to show orientation of said watermark.

10

11 7.   A method of introducing a watermark into a stream of bits representing variable

12   length codes without changing the bit rate of said stream of bits comprising,

13 maintaining a cumulative change amount which indicates the amount of the positive

14 and negative changes which are made to said codes,

15 suspending any positive changes if the cumulative change amount exceeds a pre-

16 established limit,

17 whereby the bit rate of said stream of bits is maintained constant.

18

19 8.   A system for introducing a watermark into a stream of bits representing variable

20   length codes without changing the bit rate of said stream of bits comprising,

21 means for maintaining a count of the amount of positive and negative changes

22 which are made to said codes,

23 means for suspending any positive changes if a pre-established limit is exceeded,

24 whereby the bit rate of said stream of bits is maintained constant.

25

26

16

1   9. A method for adding a multibit watermark to an image comprising,

2   generating DCT (Discreet Cosine Transform) coefficients representing said image,

3   said coefficients being arranged in blocks, said blocks being arranged into

4   macro blocks,

5   adjusting said coefficients in accordance with the bits of said watermark to embed

6   said watermark in said image, said adjustments being made in a direction that

7   sinusoids generated by said adjustments are in phase across block boundaries in

8   each macro block.

9   maintaining a cumulative change count of the positive and negative changes which

10   are made to said codes,

11   suspending any positive changes if said cumulative change count exceeds a pre-

12   established,

13   whereby said watermark forms a grid which can be detected to determine

14   orientation and scale of said watermark and the bit rate of said stream of bits is

15   maintained constant.

16

17   10. An image processing method that includes steganographically encoding an

18   input image to embed a multi-bit code therein,

19   generating DCT (Discreet Cosine Transform) coefficients representing said image,

20   said coefficients being arranged into primary size blocks,

21   arranging said DCT coefficients into macro blocks, each containing four of said

22   primary size blocks,

23   changing the coefficients in each block to encode therein a watermark in said

24   image,

25   the direction of change of said coefficients being such that the sinusoids created by

26   said changes are continuous across the primary blocks in said macro blocks,

17

1 whereby said watermark signals can be used to both carry data and to form an

2 orientation and calibration grid.

3

4 11. The method recited in claim 10 wherein said primary blocks each contain 64

5 DCT coefficients and each macro blocks contains four of said primary blocks.

6

7 12. The method of claim 7 wherein

8 negative changes are suspended if the cumulative change amount exceeds a pre-

9 established negative amount.

10

11 13. The system of claim 8 including

12 means for suspending any negative changes if said count exceeds a pre-

13 established negative limit.

14

15 14. The method of claim 9 wherein

16 negative changes are suspended if said cumulative change count exceeds a pre-

17 established negative limit.

18

19 15. A method of embedding a watermark in a stream of coded symbols that

20   represent a series of images by selectively increasing or decreasing the values

21   of said symbols, said method comprising,

22 establishing a limit on the allowable entropy of said stream of bits,

23 suspending said selective increasing if said limit is exceeded.

1

2   16. A method of embedding a watermark in a series of bit which represent an

3   image without increasing the entropy of said image beyond a pre established

4   limit, comprising the steps of:

5   changing selective bits of said image to embed said watermark,

6   maintaining a cumulative change count of the changes made to embed said

7   watermark in said image,

8   suspending changes which cause said cumulative change count to exceed a pre

9   established limit.

10

11   17. A method of embedding a watermark in a series of bit which represent an

12   image without increasing the entropy of said image beyond a pre established

13   limit comprising the steps of:

14   maintaining a count which represents the change in entropy as said watermark is

15   being embedded in said image,

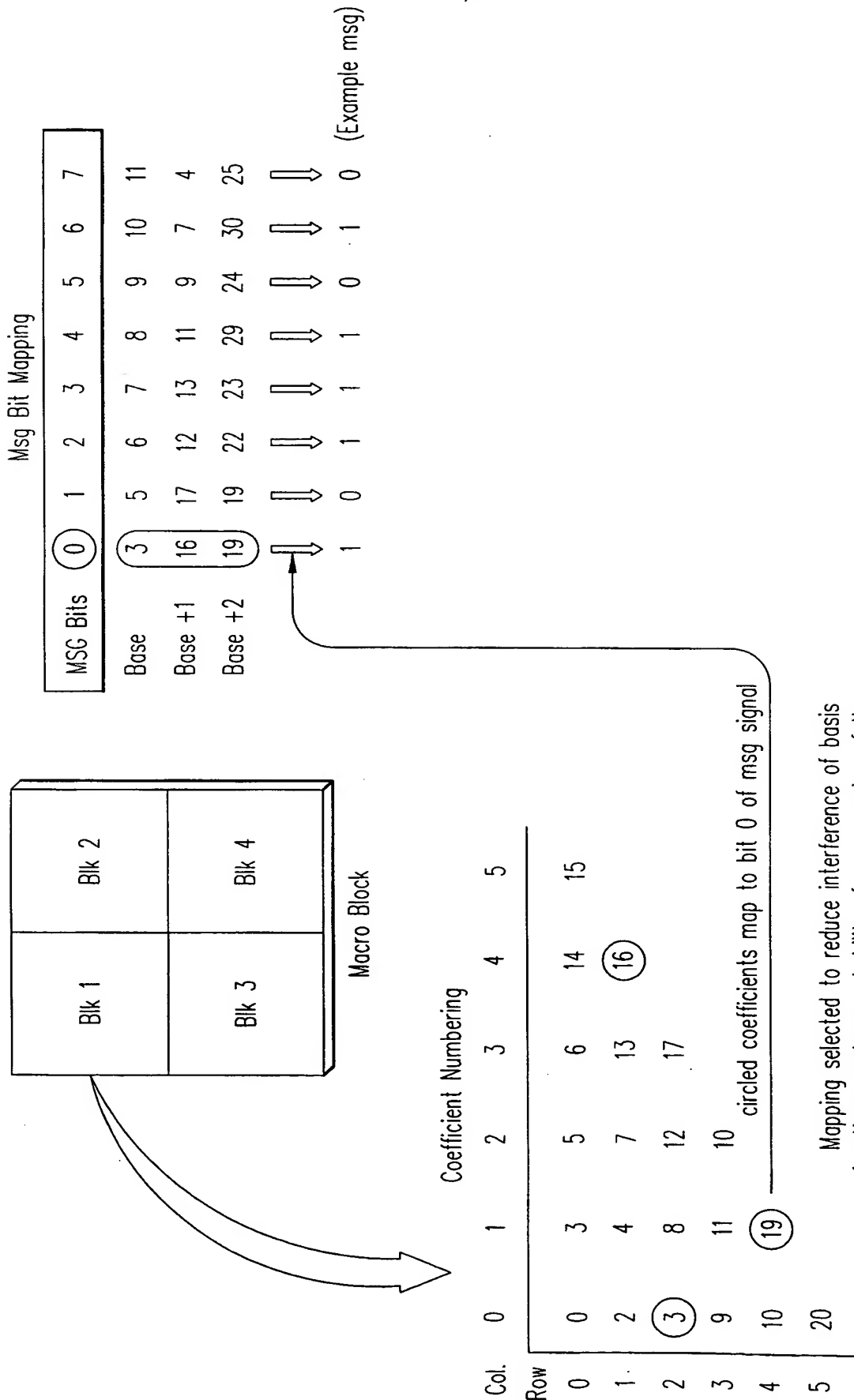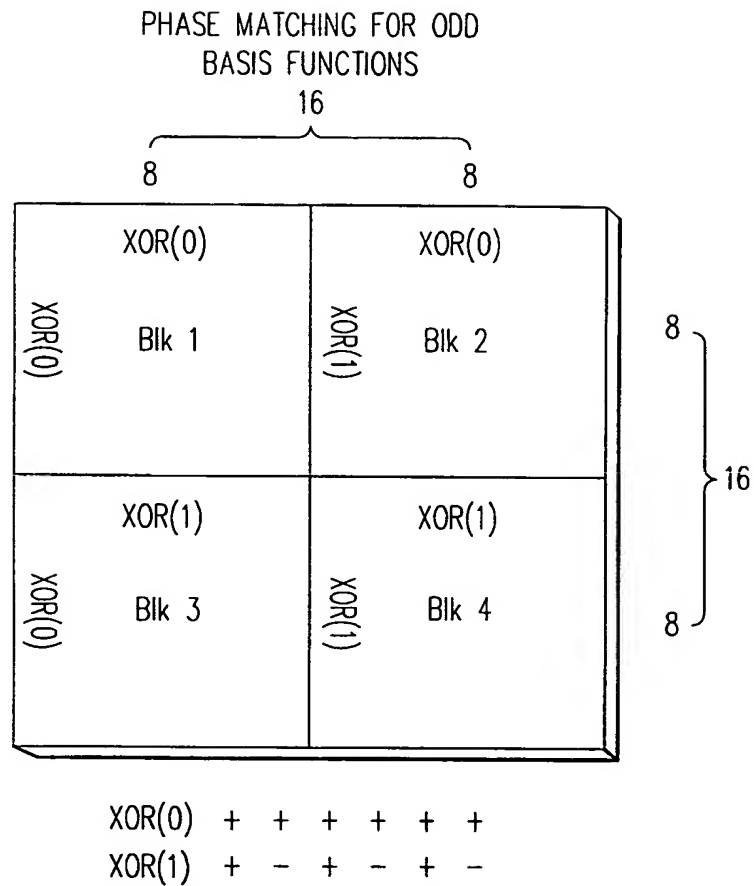16   suspending changes in said image when said count is beyond a specified limit.

17

19

1/4

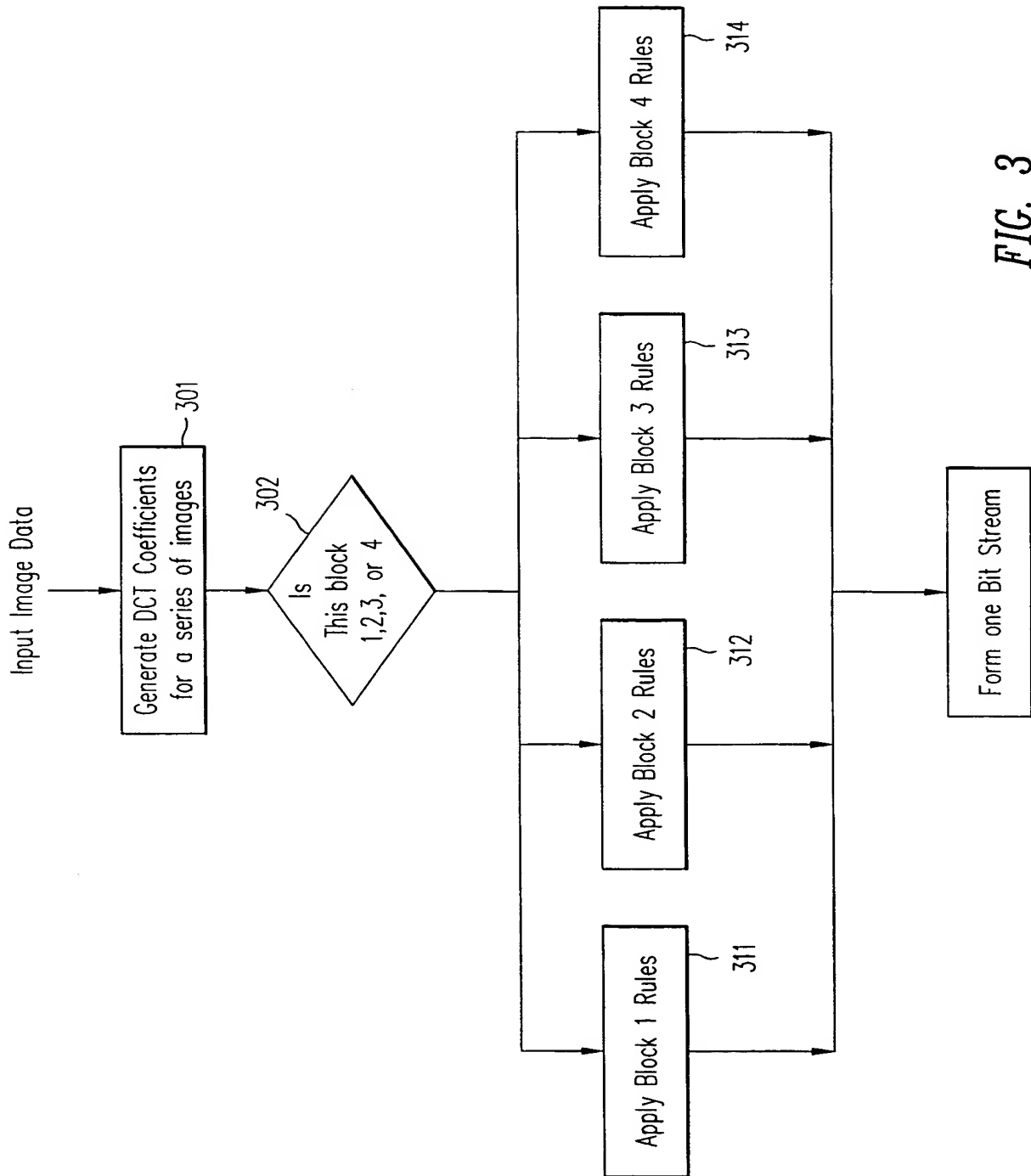FIG. 1

PHASE MATCHING FOR ODD
BASIS FUNCTIONS

XOR(0)   +   +   +   +   +   +
XOR(1)   +   −   +   −   +   −

FIG. 2

FIG. 3

Image Input

Calculate DCT
Coefficients — 401

Pos. Change limit — 403A

Cum. Change Ct. — 403C

Calculate change Needed
to add Watermark — 405

407

Is
Change positive
or negative

Positive

Negative

409

Has
pos. Limit been
reached

No

Yes

Do not change
DCT Coeff.

415

Change Coeff.

417

Change Coeff.

421

Increase Cum.
Change Ct.

425

Decrease Cum.
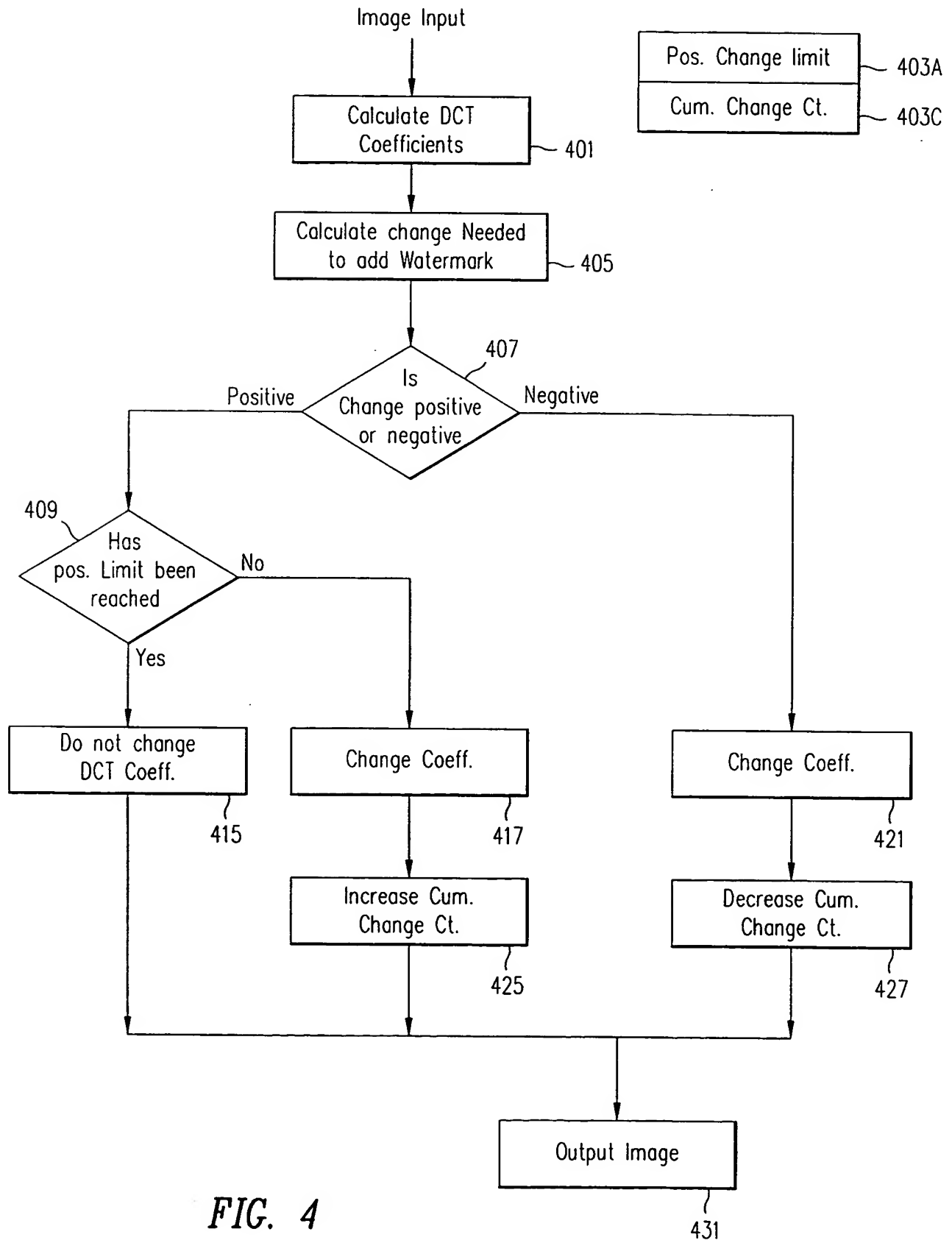Change Ct.

427

Output Image

FIG. 4

431

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/17530

A.   CLASSIFICATION OF SUBJECT MATTER

IPC(6)   :G06K 9/36, 9/46

US CL   : 382/232, 250; 380/5, 20

According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S.   :   382/232, 250, 100; 380/5, 20, 23, 49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,E	US 5,809,139 A (GIROD et al) 15 September 1998.	1-17

☐ Further documents are listed in the continuation of Box C.   ☐   See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
		"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 DECEMBER 1998	**14 JAN 1999**

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	PHUOC TRAN *Joni Hill*
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3900

Form PCT/ISA/210 (second sheet)(July 1992)★